15 April 1949

U.S. Army Epidemiological Board

Report of

ad hoc Committee on Ventilation and Air Disinfection

Appointment of this Committee was authorized by the Army Epidemiological Board at its annual meeting on 6 May 1948. The Committee discussed the task assigned to it at a meeting in Washington, D.C., on 13 September 1948 and heard reports upon specific topics assigned to individual members of the Committee as follows:

I. Epidemiological Implications of Air-disinfection and Ventilation. Topic presented by Alexander Langmuir. Chapter I of attached report prepared by John H. Dingle.

II. The Use of Ultraviolet Light for the Control of Respiratory Diseases. Topic discussed by Alexander Langmuir and Alexander Hollaender. Chapter II of attached report prepared by Alexander Langmuir.

III. The Status of Glycol Vapors as Air-disinfecting Agents. Topic presented by Clayton G. Loosli. Chapter III of attached report prepared by Clayton G. Loosli with the assistance of O. H. Robertson, William Lester, and Edward Dunklin.

IV. Effect of Humidity on Survival of Organisms in Air. Topic presented and Chapter IV of attached report prepared by Theodore T. Puck.

V. The Oiling of Floors and Bedclothes for the Suppression of Dust and Bacteria and the Control of Respiratory Tract Infections. Topic presented and Chapter V of attached report prepared by Clayton G. Loosli.

VI. General Ventilation Requirements. Topic presented and Chapter VI of attached report prepared by C. P. Yaglou.

Based upon these discussions and reports, the Committee presents the following recommendations to the Army Epidemiological Board.

1. The problem of epidemic respiratory disease among recruits is sufficiently serious to justify an expanded program of research into the causes and modes of their spread and into the means for their control. The conditions in recruit-training centers are more ideal for the conduct of control studies than are the conditions for most other population groups which are less regimented and for w hich incidence rates are generally much lower.

A solution of the problem has broad implications which extend far beyond the recruits themselves. Both civilian and military applications should follow, particularly for defense against a variety of situations where air-borne infection may occur.

2. None of the measures for the disinfection of air that have so far been made available appears to be adequate effectively to control epidemics, but there is reason to believe that some of them, either individually or in combination, might be counted upon to reduce the rates of common respiratory infections among recruits.

3. Present evidence is inadequate to justify the introduction of any one measure or combination of measures as a routine procedure in barracks.

4. The use of ultra-violet light and dust suppression measures appear to have been developed sufficiently far to permit their being tested in the field.

5. Laboratory investigations and the development of suitable equipment for the employment of disinfecting vapors and killing humidities must be carried much farther before these means can be subjected to field test. The use of chemicals other than the glycols should be considered.

6. There should be no objection to the introduction of experimental installations under conditions where there is a high incidence of respiratory disease or where there is sound epidemiological evidence of unusually high occurrence of air-borne infection.

7. The immediate objective of the Army Epidemiological Board should be to sponsor an expanded program of field, laboratory, and engineering research on air-borne infections. To this purpose, several research groups should be established in different military training centers. Each of these groups should operate under a broad directive to investigate the clinical, epidemiological, and laboratory aspects of acute respiratory diseases, with particular reference to the conduct of field studies.

8. Because of renewed recruiting it appears to be urgent to initiate experimental work as soon as practicable and to press it forward at maximum speed.

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I. Epidemiological Implications of Air-disinfection and Ventilation.

The premise on which prevention and control of "respiratory" infections by air-disinfection and ventilation is based may be stated as follows:

That these procedures, if effective, will break the chain of transmission of the disease from the infected individual to a new susceptible host by destroying the causative agent in the vehicle of transmission, that is, the air.

Entirely apart from the efficacy of the present procedures of air disinfection and ventilation in removing or destroying disease-producing agents, acceptance of the premise requires evaluation of at least the following epidemiological considerations:

A. Importance of transmission through the air in comparison to other methods of spread.

1. Quantitative data are lacking regarding the relative importance of spread through the air (by small droplets of 1-2 mu or less, droplet nuclei, and dust) and of spread by direct contact with infected secretions of the respiratory tract (kissing, contaminated objects, large droplets, etc.).

2. Presumably, however, any of these methods may be effective.

a. The assumption of "air-borne" transmission is based mainly on recovery of saprophytic and pathogenic bacteria and of viruses from the air, on experimental infection of animals, and on circumstantial evidence from observations of cross-infections and outbreaks in hospitals, laboratories, or other enclosed buildings. The relative significance of small droplets, droplet nuclei, and dust has not been determined.

b. The assumption of "contact" and "large droplet" spread is based on recovery of the agents from respiratory secretions, on experimental transmission of certain of the diseases, on the effect of aseptic techniques, etc. The relative importance of the possible means of contact spread has not been determined.

B. The physical site of transmission.

If air-borne spread is of major importance, then the procedures of control must obviously be utilized in those areas, such as barracks, movies, classrooms, and buses, where such transmission may occur. The likelihood of acquiring infection in any of these places has not been adequately determined, but may be great in some areas and slight in others.

C. The nature of the agent and dosage.

The importance of air-borne infection may vary with the nature of the infecting agent, particularly with its infectivity and stability after suspension in the air, both of which presumably influence the effective dosage. Studies such as those of Dunklin and Puck on the lethal effect of relative humidity on air-borne bacteria suggest that under certain environmental conditions air-borne transmission may be of minimal importance. Further fundamental data of this kind are needed.

The present state of knowledge of the means of transmission of respiratory infections, therefore, does not warrant the conclusion that they are principally "air-borne." The premise on which air-disinfection as a control measure is based may or may not be correct, but acceptance of it requires further studies on the nature of the causative agents, on the epidemiological behavior of spontaneous respiratory diseases of animals under laboratory conditions, and controlled field studies.

Conclusion. The various procedures for air-disinfection and ventilation can, therefore, be recommended for installation in army hospitals and barracks only on an experimental basis.

II. The Use of Ultraviolet Light for the Control of Respiratory Diseases.

The chief military interest in the use of ultraviolet (UV) irradiation for aerial disinfection lies in its potentialities for controlling epidemics of acute respiratory infections among troops, particularly among recruits in training. Discussion will be limited to this possible application.

Summary of Studies. Studies of the effectiveness of ultraviolet irradiation for the control of acute respiratory infection have been conducted in schools in and near Philadelphia and in Westchester County, New York; at the National Training School for Boys, Washington, D.C.; and among naval recruits at Camp Sampson, New York, and Great Lakes Naval Training Center, Illinois.

1. The studies among school children have been unsuccessful, as might be expected from the fact that children constitute a dispersed population and have many opportunities for exposure outside of the irradiated classrooms. Such studies, therefore, do not adequately test the potentialities of this procedure in other more regimented types of populations.

2. The studies in the National Training School for Boys which were conducted over a six-year period, 1941-1947, were also unsuccessful. UV lights were installed in two, and later in three, dormitories, while an equal number of comparable dormitories were followed as controls. Each dormitory housed from 44 to 69 boys, 12 to 19 years of age. Each of these groups constituted a semi-isolated population which had only limited contacts with the other groups and almost no contact with outside individuals except for supervisory personnel. Gross incidence rates for hospital admissions for acute respiratory diseases were high, running from 1 to 4 thousand boy-days during endemic months and reaching peaks of from 8 to 16 per thousand boy-days during epidemic months. Fluctuations in the rates between test and control groups were occasionally rather marked, as might be expected from the small population sample, but no consistent differences were observed that could be attributed to the effect of the irradiation.

Bacterial counts were made on the air of test and control dormitories over six-hour periods using three different methods simultaneously, namely: (1) open settling plates, (2) a modified Wheeler bubbler sampler, and (3) a sieve device. The counts in the irradiated dormitories tended to be somewhat lower than the counts in control dormitories, but the fluctuations were great and not consistent. In both types of dormitories the counts rose to high levels during periods of activity. The failure to achieve a greater reduction in the

bacterial populations could not be attributed to inadequacies of the installation. The intensity of radiation in the upper air spaces in the high-ceilinged rooms was estimated to be from 2½ to 5 times that recommended commercially. The irradiation was the maximum that could be tolerated by the occupants.

The failure of this study may be attributed to at least three reasons: (1) the inadequacies of the installations to induce an effective disinfection of the air of the dormitories during periods of activity; (2) contacts among the group outside of the dormitories; and (3) modes of spread of infection other than by the air-borne route.

3. The five studies among naval recruits that have been completed to date are summarized in Table I. The character of the installations, the size of the available study groups, and the epidemiological pattern of acute respiratory disease have varied each year. During each study, however, slight to moderate reductions in incidence of respiratory diseases of 20% or greater have been observed. During two of the studies, those of 1945-46 and of 1947-48, control conditions were well maintained for a sufficient period of time to suggest rather strongly that UV irradiation had induced a beneficial effect. The consistency of the observations in the other years, when study conditions were less favorable, tends to support this conclusion.

Limitations of Ultraviolet Light. The use of UV irradiation to control respiratory disease among recruits is encumbered with inherent limitations which will be difficult to overcome. The purely mechanical problems have been largely solved. Efficient fixtures and portable photometers are readily available at not-prohibitive costs. Recent installations have secured the maximum tolerable irradiation, and this has been maintained consistently through the studies.

One basic limitation is that the irradiation must be confined to the upper air spaces of occupied rooms. Since normal activity raises large numbers of bacteria into the air, these must circulate into the upper spaces before they can be killed. The observed reductions and bacterial counts of 50% to 60% probably represent near the maximum attainable by this method alone. The need appears to be for a method or combination of methods which will reduce aerial contamination at least 90% or greater and maintain it at a low level even during periods of greatest activity.

A second limitation of UV light is that it is less effective against large particles such as dust which may contain many bacteria. Further studies of UV light should be accompanied by concurrent use of effective dust suppressive measures. Such a plan is contemplated for the coming winter at Great Lakes Naval Training Center.

Limitations of Studies. Most of the studies of UV light have been deficient in another respect, namely, the lack of adequate clinical observation. A number of specific clinical and epidemiological entities of known and unknown cause are included in the broad group of acute respiratory disease. It may be expected that the effective modes of spread of these various entities differ. Some may be spread largely by droplet nuclei, others by dust, and others by direct droplets or by contact. Probably all of these modes of transmission occur in varying degrees depending upon the environmental conditions. Until these basic epidemiological characteristics are more thoroughly defined for each of the important diseases and for the particular conditions of recruit training, it will be difficult to devise or develop effective control measures.

TABLE I

Summary of Studies of Ultraviolet Irradiation

for Control of Respiratory Disease Among Naval Recruits

Year	Location	Strength of Study Group	Buildings Irradiated	Incidence and Character of Resp. Disease	Estimated Reduction in Incidence of Resp. Infections	Estimated Reduction in Bacterial Air Counts in Barracks	Comment
1943-44	Camp Sampson, N.Y.	A 2400	Barracks only	Moderate, few BHS	25%	c 50%	High intensity radiation
		B 2400	Barracks only	Moderate, few BHS	None		Low intensity radiation
1944-45	Camp Sampson, N.Y.	4000	Barracks only	BHS epidemic	?	Studies incomplete. Preliminary analysis indicated a 20% reduction in resp. disease	
1945-46	Great Lakes, Ill.	4000	Barracks, Class rooms, Recreation Halls, etc.	Severe BHS Epidemic	19%	50-90%	Floors and blankets oiled in test and control groups
1946-47	Great Lakes, Ill.	500-1200	Barracks, Class rooms, Recreation Halls, etc.	Very low, Dec.-Jan. Moderate Feb.-Mar. (Influenza A)	48% 19%	c 50%	Small, variable study group. Results of limited significance
1947-48	Great Lakes, Ill.	2000-3500	Barracks, Class rooms, Recreation Halls, etc.	Moderate, few BHS	25-40%	50-60%	Most consistent results of the 5 studies

Conclusions

1. The problem of epidemic respiratory disease among recruits is sufficiently serious to justify an expanded program of research. The conditions in recruit-training centers are more ideal for the conduct of control studies than are the conditions for most other population groups which are less regimented and for which incidence rates are generally much lower. A solution of the problem has broad implications which extend far beyond the recruits themselves. Both civilian and military applications should follow, particularly for defense against a variety of situations where air-borne infection may occur.

2. Ultraviolet irradiation has not been developed to a point where it can be recommended for routine use for the control of air-borne infections by the armed services.

3. Further studies of ultraviolet light should be conducted in conjunction with dust-suppressive measures and other possible means of reducing bacterial contamination of the air.

4. An expanded program of field, laboratory, and engineering research into the problems of air-borne infections should be undertaken. Several research groups should be established in several military training centers. Each group should operate under a broad directive to investigate the clinical, epidemiological, and laboratory aspects of acute respiratory diseases with particular reference to the conduct of field studies.

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III. The Status of Glycol Vapors as Air-disinfecting Agents.

Numerous chemicals have been employed as aerosols and vapors for the purpose of disinfecting air. With the exception of studies on the use of propylene and triethylene glycol vapors by Robertson and associates, the majority of reports have come from England. A summary of the studies in Air Hygiene made in Great Britain and in this country up to 1946 has been made by Bourdillon and colleagues as a special report (No. 262-1948) of the British Medical Research Council (1).

Hypochlorites, propylene and triethylene glycol, lactic acid, alpha-hydroxy acids, resorcinols, and alkyl resorcinols all have been found to be highly germicidal when dispersed as vapors. Each on further study and application will probably be found to have special advantages over the others in different environments. Hypochlorous acid and lactic acid vapor have been tried in a practical w ay in England as air disinfectants. Summaries, with references of studies employing these chemicals, are contained in the report by Bourdillon.

This memorandum will deal principally with investigations concerning the use of propylene and triethylene glycol vapors for the chemical disinfection of air.

The Glycol Vapors.

Propylene Glycol. In 1941, Robertson and associates first reported laboratory studies on the viricidal and bactericidal properties of propylene glycol (PG) when dispersed into the air as aerosols and vapors (2-5). Under the impetus of war preparations, these investigations were rapidly expanded. Studies of the various aspects of the problem of chemical sterilization of air with glycol vapors was one of the principal activities of the Commission on Airborne Infection from 1941 to 1945 (6). Although many of the initial laboratory investigations were made employing propylene glycol (7-9), triethylene glycol was found to be more suitable for the practical application of this form of air sterilization (10-11). Experimental studies on the germicidal action of propylene glycol vapors has also been reported by others (12-20).

Triethylene Glycol. Triethylene glycol (TEG) vapor under laboratory conditions has been shown to exert a rapid lethal action on the common respiratory disease pathogens - pneumococci types I and II; beta hemolytic streptococci, group A and C; alpha streptococci; staphylococci; meningococci; and influenza bacilli (10-11) - and on certain viruses - influenza virus (PR-8 strain); meningopneumonitis; and psittacosis viruses (10, 21, 22). The fungicidal action of triethylene glycol and the effect of propylene glycol vapor on bacterial spores have been studied by Bigg and associates (23, 24).

Toxicity of Glycols. Propylene and triethylene glycol are organic solvents. Toxicity studies in animals have been extensive in the case of PG (25-38). This is due to the fact that PG is employed as a vehicle for certain drugs, including vitamins, sulfonamides, and penicillin (39-42). Robertson and associates (43) have reported chronic toxicity studies of propylene and triethylene glycol on monkeys and rats by vapor inhalation and oral administration. Animals were exposed to high concentrations of these vapors for periods of 12 to 18 months. The doses administered represented 50 to 100 times the amount of glycol the animal could absorb by breathing air saturated with glycol. No ill effects were observed (11, 43). A review of the literature on the toxicity of these agents is also contained in this report (43). No ill effects in man residing for long periods in environments saturated with triethylene glycol have been reported (80, 81, 82, 90).

The phenomenon observed by Prigal and associates (44) of the effect of propylene glycol on increasing the antibiotic activity of human serum has no relation to the mechanism of killing action on organisms in the air. This observation needs verification.

Methods for the Study of Air Disinfection with Glycol Vapors. Robertson and associates have described in detail the construction of air-conditioned chambers and rooms for the study of air-borne infections, including air disinfection with glycol vapors (45). Likewise, Bigg, Jennings, and associates have studied the engineering problems connected with the use of glycols in large spaces for air sterilization (46-51). Descriptions of apparatus (which is now probably obsolete) for the vaporization of glycols have been reported (15,52, 55). Chemical techniques and apparatus have been described for the detection and control of glycol vapors in the air (56-59). Puck and Chaney (52) reviewed the problem of dispersion and maintenance of proper glycol concentrations in the air under varying conditions. The glycostat (59) is only available for experimental use in the laboratory of Dr. O. H. Robertson. The Precision Scientific Instrument Company is undertaking the manufacture of this apparatus. When it will be on the market cannot be determined.

The Relationship of Relative Humidity and Moist Bacterial Particles to Glycol Vapor Action. Early in the study of the bactericidal action of glycol vapors, the importance of a proper range of relative humidity was noted (8). This led to detailed studies by Puck and associates of the physico-chemical properties of glycol vapors in the air, which form the basis for the interpretation of the glycol action (60-64). The optimal relative humidity (RH) for the killing action of glycols for bacteria in different states of desiccation has not been determined. It lies approximately between the ranges of 20% and 50%. The problem of securing a minimum of 20% RH in the wintertime in the absence of air conditioning is not a difficult one. The conditions necessary for the optimal glycol vapor action have been made in summarizing reports of studies employing these chemicals (11, 52, 65-68).

It was shown early that glycols were ineffective against dried organisms (7,8-11). The hydroscopic property of glycols in liquid and vapor phase and the necessity for the presence of some moisture in the bacteria-carrying droplets form the basis for the interpretation of the germicidal action of the glycols (11,63,65). In summarizing the mechanism of action of the glycols, Robertson (11) states: "The manner in which the vapor affects the air-suspended microorganisms is expla ined on the basis of the occurrence of abundant collisions between the hydroscopic glycol molecules and the bacteria-containing droplets. With adequate amounts of vapor in the air, concentration of 70% to 80% RH glycol will be built up in the bacterial droplets in a second or two; such concentrations produce marked and rapid bactericidal action in vitro." How the

glycols produce their rapid bactericidal effect once in the bacterial cells has not yet been clearly determined (11).

The recognition of the bactericidal and viricidal action of certain ranges of rela tive humidity has been an interesting and fundamental outgrowth of the study of glycol for air disinfection (69-71). This RH range appears to be narrow and in the region of 50% both for bacteria (Streptococcus C, Pneumococcus Type I, and Staphylococcus albus), and for influenza virus (PR-8 strain). Whether the RH of this range exerts a germicidal influence on naturally dispersed pathogens has not been determined. Others have also studied the effect of temperature, humidity, and glycol vapors on the viability of air-borne bacteria (72,73).

Chemical and Inflammability Characteristics of Glycols. Glycols are alcohols and exhibit all the characteristics of alcohols. They are odorless, tasteless, slightly volatile, and miscible with water in all proportions. Atmospheres oversaturated with glycol vapors form clouds or fogs which settle on surfaces, walls, and cold windows. This is particularly true of TEG which has a low vapor pressure, 0.001 mg Hg at 25°C (75). Bigg, Jennings, and Fried (74) have studied the characteristics of PG and TEG in liquid and vapor form. Since the amount of PG and TEG vapor required is so small (0.1 mg and 0.005 mg per liter respectively) for germicidal action, it offers no fire or explosive hazard. Condensation on surfaces, however, does offer possible hazards. This fact must be taken into account in designing apparatus for the dispersal and use of glycol vapors (51,52).

Field Studies Employing Glycol Vapors

Effect on the Bacterial Content of the Air. The development of practical and accurate methods for the analysis of the bacterial content of the air (76-78) and of suitable a pparatus for the dispersion of glycol vapors in large spaces made possible the study of the effect of glycols on the bacterial content of the air and on the incidence of cross infection in hospital wards and barracks (79,79A). In 1942 and 1943, at Chanute Field, Illinois, Hamburger and associates (80) studied the effect of TEG vapor on airborne beta hemolytic streptococci in scarlet fever wards and in German measles wards where streptococcal cross infections were occurring. In the seven wards, the reduction in the number of airborne bacteria varied from 32% to 75%. In the case of beta hemolytic organisms, the reduction as noted with the Moulton sampler in the seven wards varied from 38% to 100%.

In the fall of 1943, the Commission on Airborne Infections moved to Camp Carson, Colorado. There, Hamburger and associates studied the effect of TEG vapor on airborne beta hemolytic streptococci in hospital wards alone and in combination with dust control measures (81) and at low relative humidities (82). The introduction of TEG vapor into the air, plus the application of dust control measures to the floors and bedclothes in streptococcal sore throat wards, resulted in a reduction in the number of airborne beta hemolytic streptococci of 93% when the wards were quiet and 97% during bedmaking. Dust prevention alone, however, lowered the streptococcal count by 86% during the bedmaking period but not at all when the ward was quiet. During this study, the temperature varied from 71 to 77°F and RH values from 40 to 45%. In one ward, the glycol vaporizer was under the control of the glycostat (52,59) and the average glycol concentration was 0.004 ± 0.0021 mg per liter of air. In the other ward, with a visible fog present, the glycol vapor concentration was 0.009 ± .0029 mg per liter of air. Condensation, which was not objectionable in this ward, was noted only on the cold windows.

Follow ing the above study (81), the bactericidal effect of TEG vapor on airborne beta hemolytic streptococci at RH values of 18% to 32% was found to be 88% during the quiet periods and 54% during bedmaking. These results were obtained in the presence of dust control procedures. The glycol vapor concentration was kept near the saturation point and varied from 0.0033 to 0.0084 mg per liter of air (82). In all three studies (80-82), the authors emphasize the importance of dust control measures (83) as a means of suppressing the larger dust-borne bacteria against which the glycol vapors are ineffective.

Control of Respiratory Infections in Army and Navy Camps. During the winter of 1943 and 1944, Bigg and associates (50,84,85) installed glycol apparatus (50) and studied the effect on the incidence of streptococcal infections among naval recruits living in two two-story barracks at the Great Lakes Naval Training Station, Great Lakes, Illinois (84,85). A duct system for dispersion of the glycol vapor was installed. TEG values ranged generally from 0.0025 to 0.003 mg per liter of air. The temperature varied from 72 to 75°F and the humidity was in the "optimal range." No figures are given for the reduction of beta hemolytic streptococci in the air, but large daily fluctuations in the bacterial count were noted. Studies were made on three groups of 640 men observed for six-week intervals and equally divided into a test (glycol) and control group. An overall reduction in the airborne disease of 12% was observed for the entire period but during the final seventeen days the reduction was 64%. There appeared to be a reduction in the number of carriers of beta hemolytic streptococci in the men exposed to the glycol vapors (85).

Again during the winter of 1945 and 1946, Bigg and associates (51,86) made a study of the control of airborne infections among A.A.F. recruits at Chanute Field, Illinois, by the use of TEG vapor in sleeping quarters (barracks). Equipment (51) was similar to that employed in the previous study (50). The incidence of illness based on hospital admissions from a test squadron (500 men) and a control squadron (500 men) were observed from December 1, 1945, to January 24, 1946, as a pretest period, and from January 25 to April 5, 1946 (10 weeks) as the test period when one squadron lived in glycolized barracks. During the pretest period, a disease rate of 262 per thousand per annum occurred in the control group and 272 per thousand per annum in the test group; during the period of actual test, the rates were 714 and 384 respectively. This, according to the authors, "represents a 46.2% reduction in disease incidence" (51,86). Although interesting, the small numbers of men and the short period of observations make the above data probably not statistically significant.

Control of Infections in Hospital Wards. Harris and Stokes observed the effect of PG vapor and later TEG vapor on the incidence of respiratory infections in a children's convalescent home over a three-year period, 1941 to 1944 (87,88,89). The clinical diagnoses of the infections were the common cold, tracheobronchitis, otitis media, and acute pharyngitis. During the study, they observed only thirteen infections on the wards during the test periods compared to 132 during the control periods. Exposed plate counts for bacteria showed a fivefold reduction during the glycolized periods. The concentration of PG in the air varied from 0.048 to 0.094 mg per liter and during the use of TEG the concentration varied from 0.0018 mg per liter to 0.0033 mg per liter of air, as determined by chemical analysis (56-58). TEG at the fog level was noted to condense on the windows, floors, and objects in the ward.

This study appears to have been made under highly favorable circumstances. The wards were essentially quiet ones with a limited amount of coming and going of visitors, and of professional and nursing staff. Very few of the children were acutely ill. Most of them were bedfast providing very little contact with one another and opportunity for direct droplet spread of infection.

Loosli and associates (90) conducted a study on the control of cross infections by the use of TEG vapor on the infants' wards of the Harriet Lane Home, Johns Hopkins Hospital, from October 15, 1945, to May 1, 1946. The test and control wards were comparable in size, physical set-up, number of patients(140 test; 130 control), hospital days (2221 test and 2402 control), and the kinds of primary diseases treated. The apparatus was that previously employed by the Commission in the Camp Carson studies (52,81,82.) It performed satisfactorily, and there were no complaints from attendants, nurses, or doctors who worked in the glycolized ward. No injurious effects of the vapor was noted on the skin or respiratory tract of infants who were on the test ward for several weeks to several months (90).

On account of the general use of chemotherapy, both for prophylaxis and treatment, it was necessary to consider this factor in the analysis of data. The results of the study are shown in Tables II and III.

Table II

Comparison of Environments of the Wards and the Bacterial Content of the Air

Wards	Control	Test	Reduction %
Number of days on which air samples were taken	43	43	..
Mean number of patients	14.7	13.8	..
Mean relative humidity	36.6	40.0	..
Mean per cent saturation of triethylene glycol	0.	60.0	..
Mean number settling plates exposed for 1 hour (8 to 9 a.m.)	11	11	..
Mean number bacteria per "settling plate"	149	103	31
Mean number cubic feet of air samples (Tolin-bubbler-sampler)	215	220	..
Mean number bacteria per cubic foot of air	90	26	70

Table III

Incidents of Infections Developing on Test and Control Wards in Relation to Chemotherapy

	Control Ward			Test Ward Triethylene Glycol Vapor		
	Chemo-therapy	No Chemo-therapy	Total	Chemo-therapy	No Chemo-therapy	Total
Total Hospital Days	960	1,442	2,402	985	1,236	2,221
A. Clinical infections:						
1. Non-specific (URI) number	11	15	26	6	9	15
Rate per 1,000 hospital days	11.4	10.4	10.9	6.1	7.5	6.7
2. Specific bacterial number	2	18	20	2	9	11
Rate per 1,000 hospital days	2.1	12.4	8.3	2.0	7.5	4.9
B. Inapparent bacterial infections:						
Number	13	28	41	13	24	37
Rate per 1,000 hospital days	13.5	19.4	17.1	13.2	19.4	16.6

No dust control measures were employed during the Harriet Lane Home study. This is reflected in the comparatively low reduction in the number of bacteria on the test ward from the settling plate counts. The data on clinical infections are in favor of glycol vapor but are not statistically significant.

The significantly low incidence of clinical, bacterial infections in the groups receiving antibiotics compared to the rate among those not receiving drugs on both wards shows that penicillin and sulfadiazine also acted prophylactically to prevent the pathogens from invading the host tissues. These observations emphasize the fact that the simple procedure of giving antibiotics for the duration of a child's stay in the hospital must also be considered in the evaluation of methods for the control of hospital cross infections due to bacteria (90).

The Harriet Lane Home is a teaching hospital for medical students, nurses, a large group of house staff, and attending men, and there was continuous traffic by the personnel into and out of the wards for the greater part of the day. Many of the infants were acutely ill and often required intimate care by the attendant, nurse, or doctor. During emergencies, cubicle isolation and aseptic techniques were sometimes broken. This situation existed equally on both the test and control wards. Thus, the conditions under which this study was conducted constituted an unusually difficult test for evaluating the use of glycol vapors for the prevention of hospital infections. As previously indicated, there were many opportunities for the spread of infections other than by the airborne route. Recognizing this, the reduction in clinical infections which did occur on the test ward may represent that proportion which were airborne and thus prevented by glycol vapor.

Studies on the Use of Glycols since the War. At the termination of the Harriet Lane Home study, the major equipment was transferred to New York University Medical School, where Dr. Emmet Holt and associates planned to carry on studies of the use of glycol vapors in contagious disease children's wards. Experimental wards were prepared and some preliminary observations made. At this writing, the present status of this project is not known, and there appears to be no other controlled study for the evaluation of glycols as disinfecting agents in progress at the present time.

Further Laboratory Investigations

Dr. Robertson and associates have continued an active program of investigation on all aspects of the problem of disinfection with glycols. In a recent report (91) they give results of an investigation concerning the bactericidal activity in vitro of some 18 compounds. Most of these were glycols. A third glycol (dipropylene glycol, DPG) was found to possess certain properties which make it acceptable for use as an aerial disinfectant in atmospheres occupied by human beings. It was found that the in vitro killing rate of PG, DPG, and TEG increased with the increase in concentration of the agents. Most interesting was the observation that even in the test tube a minimum quantity of water is necessary for rapid lethal action.

Additional studies in progress or soon to be published by Robertson and his group (92) include: (1) effect of RH on the viability of airborne bacteria and viruses (Influenza); (2) methods for rapidly drying bacteria and viruses; (3) effect of relative humidity on the survival of bacteria and viruses on fabrics and surfaces; (4) new methods for collecting bacteria and viruses from the air; (5) methods for sizing bacteria and virus-carrying particles; (6) particle size and infectivity in the air; (7) wetability of dust-borne bacterial particles; (8) mechanism of action of aerial bactericides, including the effect of temperature, relative humidity, and concentration of the vapor in the killing process. These investigations are fundamental with respect to the application of glycol vapors, or other chemical agents, for the disinfection of air.

Contemplated Study for the Practical Application of Glycol Vapors for the Control of Respiratory Tract Infections. Preliminary plans, which have not yet been approved by the Bureau of Medicine, have been drawn up for a long-term study (5 years) employing glycol vapors as a means of controlling streptococcal infections among recruits at the Great Lakes Naval Training Station, Great Lakes, Illinois, as part of the research program of Naval Medical Research Unit No. 4, headed by Commander John Seal. Collaborating on the project would be members of Dr. Robertson's research team (Dr. William Lester), Dr. B. H. Jennings of Northwestern University, Dr. Alexander Langmuir of Johns Hopkins University, a nd possibly others. In the opinion of Dr. Clayton G. Loosli, who is a consultant at Great Lakes, this study is most important, as it will be conducted in the same barracks in which the ultra-violet light studies have been made for the past four years, thus providing an opportunity adequately to compare the efficiency of these two most important methods of air disinfection. In addition, the environment at the Great Lakes Naval Training Station provides unusual opportunities for basic studies on the mechanisms involved in the spread of beta hemolytic streptococcal infections. The studies can be made utilizing newer sampling methods for the purpose of analyzing the particle size distribution of bacteria-carrying droplets in the environment and their r esponse to ultra-violet light or glycol vapor. Such studies, coupled with repeated quantitative determinations of air contamination, in terms of total bacteria per cubic foot and beta hemolytic streptococci per cubic foot and combined with adequate epidemiologic studies would be expected to yield data of great practical importance. Furthermore, the efficacy of the various methods for the control of airborne infection could be determined in terms of their effect on various particle sizes and from these data extrapolation to the determination of the "dangerous" particle sizes from the standpoint of human infection should be possible.

Commercial Production of Apparatus for the Dispersion and Control of Glycol Vapors

Glycol Vaporizers. During the past three years, numerous companies have been organized for the sole purpose of exploiting the use of glycol as a means of "preventing colds." Advertisements of apparatus (glycol vapors) of a wide variety of design are appearing daily in the press. It is obvious from the description in the brochures that the manufacturers are entirely unaware of the principles on which air disinfection with glycol vapors is based, although certain early articles by Dr. Robertson and associates are quoted. A number of "vaporizers" have been found to be mechanically inadequate. The commercial exploitation of glycol vaporizers for home, school, and industry as a panacea for the "prevention of colds" is most unfortunate. The basis for much of the exploitation, apparently, can be laid to an article which appeared in Hygeia in April, 1948 (93). Written by a so-called science writer with the help of members of the Air Purification Service which makes vaporizers, this article has been extensively publicized in the Readers' Digest and other magazines of wide circulation.

In an effort to combat some of the claims of manufacturers, an editorial has been written by the subcommittee of the American Public Health Association and published in the February number of the Association's Journal (94). This article calls attention to the limitation of our knowledge and probable use of glycols for the prevention of respiratory tract and other infections. The subcommittee is working with the Secretary of the Council on Physical Medicine of the American Medical Association for the purpose of drawing up specifications and standards of operation of glycol vaporizers. It is also preparing an editorial for publication in the Association's Journal which, it is hoped, will

help counteract the unfortunate effect of the Hygeia article. At the present time, the Council on Physical Medicine of the American Medical Association (95) is of the opinion "that evidence did not justify the acceptance of generators of glycol vapors in practical application, such as schools, offices, theaters, and public buildings because the results are not convincing."

The DeCamp Corporation, Chicago, and the Air Purification Service, New York, make certain models of glycol vaporizers which appear to be mechanically sound and of sufficient capacity for use in large spaces.

Glycostats. The only available glycostats (32,59) for controlling the glycol concentration in the air are the few made in the laboratory of Dr. Robertson. These are in continuous use in the laboratory and are not available for field study. The Precision Scientific Instrument Company, Chicago, is in the process of making glycostats for commercial use. The status of development of this apparatus by the company is not known. More sensitive chemical methods are being developed in Dr. Robertson's laboratory. If adequately planned and carried out, a study could possibly be made of the use of glycols without a glycostat.

Summary and Conclusions

1. Tremendous progress has been made concerning the conditions which are necessary for the utilization of glycol vapors for air disinfection purposes, since they were first employed as ingredients of germicidal aerosols (96,97). Much remains to be done. Summarizing the available data on the use of glycols, the Committee on Sanitary Engineering of the Division of Medical Sciences of the National Research Council (98) and the Subcommittee for the Evaluation of Methods to Control Airborne Infection of the Committee of Research and Standards of the American Public Health Association (99,100) do not recommend general application of glycol vapors for disinfecting air in homes, offices, schools, hospitals, barracks, or places of public congregation.

2. Further studies to evaluate the use of glycol vapors as an air disinfection method are needed. These can best be done in military installations and hospital wards where the prevalence of respiratory infections and cross infections is often high and where the environmental air is known to become highly contaminated (101-103). In the absence of significant data, the use of glycol for air disinfection in the home, school, office, theaters, barracks, or hospitals, at the present time must be considered experimental (94,98,100).

3. The evaluation of glycols for air disinfection in relation to other methods, such as ultra-violet irradiation (104) and dust suppression (83,105), is needed (106). The prophylactic use of antibiotics for the control of infections in relation to the above methods needs further study.

4. Adequate evaluation of glycols for air disinfection will depend on further knowledge of the fundamental nature of airborne infection and its importance in relation to other modes of spread. Laboratory studies by experienced personnel in this field should be encouraged (22).

5. The evaluation of the germicidal action of a glycol vapor on airborne bacteria and viruses is complex (1,11,63,64). As Lidwell and associates state, the possible variables for any chemical are: (1) physical factors (humidity, temperature and radiation); (2) bacterial factors (species, size of inoculum, whether dry or freshly sprayed from culture, nature of culture medium, and size of airborne particles); (3) factors related to bactericide concentration, and

rate of mixing with bacterial aerosol and vapor. The same factors, plus additional ones, must be considered in the practical evaluation of a glycol vapor (1,11,52,63,64,68).

6. Dr. Lester (68) has summarized certain essential information on the use of glycol vapor for air disinfection as follows: "Continuous dispersal of the glycol vapor is essential for air disinfection because of the following reasons: (1) 50% to 70% of the vapor dispersed into the air is lost rapidly by condensation on surfaces and air-borne dust particles, and further loss is caused by the exchange of vapor-containing air through open doors or windows; (2) aerial contamination of inhabited spaces is a continuous process and hence concentrations of the glycol vapor sufficient to kill the infectious agents must always be present; and (3) the killing action of the glycol, while very rapid for moist, freshly-expelled bacteria, requires some time for the dried microorganisms originating from secondary reservoirs such as dust.

"In addition to the continuous dispersion, the glycol vapor must be distributed uniformly throughout the treated space and, for this, the use of electric fans may be necessary. When the introduction of the glycol vapor is incorporated into an air-conditioning system, even distribution of the vapor should occur if the sys tem has been properly devised.

"Since triethylene glycol evaporates very slowly, it is necessary to use heat for vaporization. The temperature to be used for producing the vapor should be less than 260°F because above this value the glycol begins to decompose. Hence, in order to evaporate sufficient glycol at temperatures below 260°F extended evaporating surfaces are used. This must be considered in the design of any vaporizing unit.

"As was stated above, triethylene glycol has been found to be most effective for air disinfection at concentrations ranging between 50% and 100% saturation of the air with the vapor which, in terms of amounts of glycol, is between two and four micrograms of triethylene glycol per liter of air, under ordinary conditions of temperature and humidity. If the glycol saturation falls below 50%, progressively less effect will occur and if the saturation becomes 100%, or greater, a fog will appear which might not be esthetically acceptable. Because of these limitations it is advised that large-scale installations have available adequate means of determining the saturation of glycol. In small installations, it is advisable to maintain vaporization at or near the fog level to insure the maintenance of disinfecting concentrations of the vapor.

"The relative humidity of the air in the treated space is a critical factor in determining the efficacy of glycol vapor and should be within the range of 20 to 50%."

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IV. Effect of Humidity on Survival of Organisms in Air.

An understanding of the role of the atmospheric relative humidity in influencing the spread of air-borne diseases is far from complete. The humidity has been shown to exert the following actions, which may either affect various stages in the natural process of air-borne infection or measures proposed to control atmospheric contagion:

1. Pathogenic micro-organisms dispersed into the air from saliva are subjected to a destructive action which in the case of some agents, at least, is highly effective if the relative humidity is within the range of 45% to 55%. If the atmospheric moisture content is either higher or lower than these limits, the micro-organisms may survive for long periods. This effect is due to salt, originally present in minute amounts in the suspending liquid, but which becomes concentrated to a lethal level when the water evaporates.

The relative humidity also can influence the survival of surface-contaminating micro-organisms.

2. Host resistance to infection may be conditioned by the relative humidity. One mechanism which has been elucidated is the drying of surfaces of respiratory-tract membranes at low relative humidity, which diminishes their effectiveness in removing foreign particles,

3. The action of any water-soluble germicidal vapor depends upon the humidity in such a way as to be maximal at some intermediate value of the atmospheric water content. This behavior is due to the fact that at high humidities the concentration of germicide which condenses on the bacterial particle is necessarily low; at low humidities a high germicide concentration at the bacterial surface is thermodynamically possible, but the rate of condensation may become too small for effective action.

4. It has been claimed that the relative humidity also influences the germicidal action of ultra-violet radiation, but the nature of this effect has not yet been made clear.

Further laboratory study of each of these actions is necessary. Careful investigations may be expected to increase understanding of the factors involved in the natural spread of air-borne disease, and in designing measures for its control.

Conclusion. Since as far as is now known, very low relative humidities always operate in favor of the infective processes, engineering studies, on the feasibility of maintaining humidities of around 40% in barracks, hospital wards, and similar installations, may be recommended.

If such engineering operations can be made practicable, and if epidemiological considerations warrant, a study testing whether humidity control - both alone and in conjunction with other measures - might influence human disease under certain types of conditions, should be considered.

V. The Oiling of Floors and Bedclothes for the Suppression of Dust and Bacteria and the Control of Respiratory Tract Infections.

Numerous studies have been reported which show that individuals ill with respiratory tract infections contaminate their environment with the specific etiologic agents and that these agents may survive for long periods of time (1-20) in dust on floors and in bedclothes. Contaminated dust has also been shown to be responsible for laboratory infections (21-24). What role these "environmental reservoirs" of bacteria and viruses play in the spread of infections in laboratories, barracks, hospital wards, factories, schools, and homes is not clearly established. The marked rise in the bacterial count in hospital wards and barracks during bedmaking and floor-sweeping has led an increasing number of observers to conclude that infections acquired in the respiratory tract from the inhalation of dust-borne bacteria and viruses are far more prevalent than generally recognized. As a result of this observation, studies by English (25-31) and American workers (32-34) have been directed toward the development of adequate dust and lint control measures and the evaluation of these methods as a means of preventing respiratory tract infections in barracks and cross-infection in streptococcal and measles wards in hospitals (35,36).

Methods. Investigations in England (25-31) and in this country (32,33) before and during World War II established that the application of oil to floors and bedding is the most efficient method for controlling the aerial dissemination of dust and bacteria. A summary of the above studies up to 1944 was made by Loosli and Robertson (37). Two additional reports giving summaries of studies by various workers concerning the development and use of dust suppressive measures have been made (38,39). Since the last report, two additional studies carried on by the Navy have been reported (40,41). A brief summary of the recommended dust suppressive methods and results of pertinent studies is given below.

Oiling Floors. Most commercial companies make a special grade of floor oil which meets government specifications (42). The cost of such oil varies from 25 to 28 cents a gallon. One gallon covers from 150 to 200 sq. ft. of soft wood barracks floor. Such floors retain their dust-holding properties for as long as eight months if cared for properly, that is, mopped only with hot water and without soap or alkalis. Oil can be applied to hardwood or composition floors in sweeping compounds (sawdust) or by mopping with a 10% to 20% solution of T-13 oil emulsion. To avoid slipperiness, only a thin film of oil can be applied to hardwood, varnished, or hospital floors. Thus, to maintain a dust-holding surface, repeated applications of small amounts of oil are required (37-38).

Oiling Bedclothes. Several formulae for the application of oil to bedclothes have been reported (32, 33, 40, 43, 44). The T-13 oil-in-water emulsion base developed by the Commission on Air-borne Infections (33,34) has been shown to be a practical method for the application of oil to bedding (cottons and woolens) and wearing apparel. The T-13 oil emulsion base is prepared, at present, by the Baxeal Laboratories, 430 West 37th Street, Chicago 9, Illinois. The cost is $1.90 (f.o.b.) a gallon delivered in 5- to 50-gallon open-head, lacquered, rust-resisting drums. This company can manufacture twenty-five 55-gallon barrels a day. At the time of the Fort Bragg studies (44,47), the cost was $1.10 a gallon (f.o.b.) or 6 cents per blanket and 1 cent per sheet.

During the study of the evaluation of the T-13 formula, it was shown that blankets with dust-holding amounts of oil (2% to 3% by weight of the blanket) lost little or none of the oil on repeated washing (3 times) even in the

strongest alkali soaps and wide ranges in water temperature. It was also shown that oiled but washed blankets were just as dust-holding as were freshly oiled blankets for a period up to 14 weeks in oiled floor barracks. On the other hand, sheets containing from 2% to 3% oil lost approximately one-half of it during washing and required retreatment in a 0.5% oil emulsion solution (33,44).

Oil-treated blankets and sheets were essentially indistinguishable from untreated fabrics in appearance, texture, and touch. No complaints were received from several thousand men who slept in oiled bedding during the 6-month study at Fort Bragg (47).

Control of Dust-borne Bacteria by Oiling Floors. Van den Ende, Lush, and Edwards, 1940, were the first to call attention to the dust and bacteria-holding properties of crude paraffin oil (spindle oil) when applied to floors (26). They carried out an experiment in which they beat blankets artifically seeded with hemolytic streptococci into comparable rooms, one with oiled and the other with untreated floors. After allowing time for the bacteria to settle, agar plates were placed in each room and the floors were swept. The resulting collection of streptococci on plates showed a marked reduction (89%) in the aerial contamination of the room with the oiled floors. These observations were confirmed by the study of the effects of oiled floors in controlling naturally-dispersed bacteria in Army canteens and hospital wards, by Thomas (28), diphtheria wards, by Crosbie and Wright (11), hospital wards by U.S. Naval Medical Record Unit No. 1*, and hospital wards and barracks, by Robertson and associates (32,34). Andrewes (25), reviewing the methods of controlling the spread of infectious diseases in crowded public places, recommended strongly that wherever possible floors should be oiled to prevent dissemination of dust-borne pathogens.

Control of Bacteria by Oiling Bedclothes. Treatment of bedclothes with dust-laying oils for the purpose of reducing dust-borne infections in hospitals was first reported by Andrewes and co-workers (25). Oiled and unoiled blanket strips were artificially infected by coarse spray of hemolytic streptococci or staphlococci, then dried and subsequently beaten in a room, and plates exposed for five minutes. In the case of all wool, oiled blankets, there was a 95% decrease in the number of bacteria liberated into the air. These observations were confirmed by subsequent studies of English (27,29,31,43) and American workers (32,33,40,44) employing various methods of application of oil to the blankets.

Oiling Floors and Bedclothes as a Means of Controlling Respiratory Tract Infections. An investigation was carried out in an Army camp in England (45) from December 1942 through March 1943, on the control of respiratory tract infections by the use of oiled floors only. The average weekly infection rate per 1,000 in the test unit was 7 compared to 38 for the control. An outbreak of acute respiratory disease of epidemic proportions occurred in the control unit with no increase in the rate of infection in the test unit.

Similar studies were done by the Commission on Air-borne Infections at Camp Carson, Colorado, from March to June, 1944 (46). Oiled floors alone, as well as oiled floors and oiled bedclothes, were tested. Group A, comprising approximately 3,800 men in each of the test and control units, was used to observe the effect of oiled floors alone on the incidence of respiratory disease in men living in barracks. The weekly hospital admission rate per thousand was 4.0 for the test unit, and 5.9 for the control unit. These rates were too low

*U.S.Naval Bulletin 42:1288, 1944.

to evaluate the use of oiled floors alone as a means of controlling respiratory disease.

Groups B and C were employed to evaluate the use of oiled floors plus oiled bedding. In Group B there were approximately 1,600 men each in the test and control units, and the average weekly admission rate per thousand for respiratory disease was respectively 6.2 and 11.5. Group C was an organization composed essentially of new recruits with approximately 350 men each in the test and control units. The average weekly admission rate per thousand for respiratory disease was 13.3 from the test, and 28 from the control unit. In Groups B and C, approximately 50% of the hospital admissions for respiratory disease from the test and control units had throats positive for hemolytic streptococci. The number of cases and the difference in rates of admissions from the oiled barracks compared to the control were sufficiently great to conclude that oiled floors and bedding effected a significant reduction in the number of admissions for respiratory disease (46).

A more detailed study on the control of respiratory disease in new recruits, employing oil to floors and bedclothes, was carried out jointly by the Commission on Acute Respiratory Diseases and the Commission on Air-borne Infections at Fort Bragg, North Carolina, from October 1944 to May 1945 (47).

During the first period of low endemic occurrence of respiratory disease, there was suggestive evidence that the procedure reduced the incidence of hospitalized illness. There was little or no effect during the epidemic occurrence of acute, undifferentiated respiratory disease. Hemolytic streptococcal infections and respiratory diseases of known etiology did not occur with sufficient frequency for the effect of the oiling procedures to be evaluated. The difference in the results obtained at Camp Carson compared to those at Fort Bragg may have been due to the high incidence of streptococcal disease at the former camp.

In 1944, Wright and co-workers (48) reported a highly favorable study on the use of oiled bedclothes and floors in preventing cross-infections due to the hemolytic streptococcus in measles wards. A preliminary 3-week period of employing oiled floors alone showed no reduction in the incidence of cross-infections in the test compared to the control ward. During the following 9 weeks, however, when dust-suppressive measures were applied to the floors, bedclothes, garments, and all other cotton and woolen fabrics, a marked reduction in streptococcal infections in the test ward occurred. Group A, type 6 streptococcus was employed as the index of contamination of the wards and of cross-infections. During the 9-week period of study, the cross-infection rate was 18.6% in the test ward, and 73.3% in the control, while the complication rate was only 2.8% in the test ward, compared to 14.3% in the control (48).

Recognizing the difficulty of drawing conclusions with respect to the value of dust control procedures for the prevention of hospital cross-infections from a single study, Wright and associates carried out a similar study during the following year (1945) (49) in the measles wards of another hospital. Similar methods were employed, and a more rigid aseptic technique was instituted to reduce the possibility of other modes of spread. As was found in their previous study, the oiling methods effected a marked reduction in the total bacterial and streptococcal counts in the air of the test ward.

In contrast to the favorable clinical results obtained in their 1943 study (48), the cross-infection rate, although low on both wards in 1945, was actually higher (20%) in the unoiled ward. The authors found these results difficult to explain. They point out that both wards had a comparatively low cross-

infection rate of the same order as the 18.6% rate which was regarded as satisfactory for the oiled ward in the 1943 investigation. The low degree of aerial contamination by streptococci in wards suggested that the cross-infections were caused by a mode of spread which was not air-borne. Two factors are presented which possibly explain the higher cross-infection rate in the test ward; (1) a higher admission rate of type 12 streptococcus, the only streptococcal type which showed signs of "communicability" and "virulence"; and (2) a higher admission rate of skin sepsis and streptococcal otorrhea cases.

The absence of a markedly virulent "communicable" strain of streptococcus from the wards in the 1945 study (49) was in striking contrast to the condition on the wards in 1943. In the latter investigation, only one group A streptococcal type (type 6) was responsible for the high cross-infection rate and complications in both wards before and in the control ward after oiling methods were instituted. In the 1945 study, numerous types and groups of hemolytic streptococci were isolated from the cases of cross-infection.

Wright and her co-workers (49) conclude "that the results of the 1945 investigation need in now way discourage further trials of dust suppression by oiling. Should unfavorable conditions of 1943 recur in subsequent measles epidemics, dust control may again assume importance as a measure of preventing infection."

Recently two reports (40,41) have appeared of studies carried on in Navy installations relative to the use of dust-control measures for the control of respiratory infections among Navy personnel. Shechmeister and associates (40) investigated methods as well as application of oiling as a means of controlling respiratory diseases. Treatment of floors and blankets with a germicidal (Roccal) oil-in-water emulsion reduced the number of organisms in the air 33 to 63%. They concluded that their oiling program effected a slight but significant reduction in the beta type hemolytic streptococcus carrier rates in the group living in oiled environments but had no effect on the incidence of minor respiratory illnesses.

Miller and co-workers (41) found that dust-control measures produced a significant reduction in the bacterial content of the air, blanket dust, and floor dust, but did not produce a consistent reduction in disease rates, whereas oiling, plus ultra-violet radiation, yielded a statistically significant reduction of 19%. They point out that the superb cleaning and scrubbing of the control barracks in the dust-control study exposed a variable unknown value that may have influenced the comparative results. They state further that, "In view of the favorable reports of dust suppression by oiling, our experience at Great Lakes emphasizes the fact that aggressive and thorough cleaning of barracks is still one of the most valuable means at our disposal in intercepting the passage of infectious agents from one individual to another."

Summary and Conclusions.

1. Contaminated dust in certain environments plays a part in the spread of some respiratory tract infections (bacterial). The importance of this mode of spread in relation to other means is not yet established. Further study of the role dust-borne bacteria and virus play in the spread of air-borne infections is needed.

2. Practical methods for the suppression of dust and dust-borne bacteria and viruses are available. These constitute the use of oil to floors and bedclothes. The technique as recommended by the Commission on Air-borne Infections for application of oil to bedclothes is recommended. A single applica-

tion of oil to bedclothes is recommended. A single application of oil to blankets would, in all probability, be sufficient to insure its dust-holding property for the duration of the life of the blanket. Oil to sheets would require repeated application.

3. Although oil to floors and bedclothes effects a marked reduction in the number of bacteria dispersed into the air of barracks and wards during bed-making and floor-sweeping, studies on the use of these methods for the control of respiratory tract infections are inconclusive. On the basis of available evidence, dust-suppressive measures would effect a reduction of the number of streptococcal infections in wards and barracks where the disease incidence is high. Dust control in any environment should be considered a means of "good housekeeping" (51). These methods should be used in conjunction with other methods of air disinfection, such as ultra-violet light and glycol vapors, which have no effect on bacteria in large dust particles (41,50).

4. Studies should be set up to evaluate further the use of dust-suppressive measures for the control of respiratory tract infections, particularly of streptococcal and pneumococcal etiology. These should be carried out in areas only where the incidence is high. With sufficient personnel, field studies combining clinical epidemiological, and the evaluation of methods of control with chemotherapy and dust-suppressive measures and other methods can best be done by a single research team.

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VI. General Ventilation Requirements.

The purpose of ventilation in ordinary living and sleeping quarters is to maintain a comfortable temperature and to remove objectionable odors. Current practice allows an outside air supply of 600 to 900 cubic feet per hour per occupant for dilution of body odors, and as much as 1200 cubic feet for the removal of tobacco smoke. Where the air space allotment per person is not less than 600 cubic feet, leakage of air through ordinary window and door cracks (1 to 2 air changes per hour) is usually sufficient to provide for the minimum requirements of occupants in cold weather. Fans must be used in densely occupied places, or in large rooms where it is difficult to obtain enough fresh air in interior areas without creating drafts near the windows.

Special consideration must be given to the ventilation of field tents and shelters heated by stoves that are likely to contaminate the air with carbon monoxide. Natural ventilation in these enclosures varies greatly depending largely on porosity of tent fabric, wind velocity, and temperature difference. Shelters made of impervious canvas walls, such as the Jamesway Shelter, allow a leakage of less than one change of air per hour, mostly through cracks in floor, doors, and windows. Wind and temperature difference have no great effect on the ventilation of this shelter. Untreated porous shelters, on the other hand, such as the light-weight pyramidal tent, allow too much leakage; the maximum observed was thirteen air changes per hour with a wind velocity of twenty miles per hour. In any case, reliance must be placed on preventing escape of CO from stoves into the living spaces, rather than on dilution of CO by ventilation.

From the standpoint of air infection, the ordinary amounts of ventilation are inadequate for controlling bacterial pollution of air in occupied rooms. Too great an air supply may even increase pollution by blowing off deposits of dusts and microorganisms from the floor. Much depends on the type of air distribution system used, the number and activity of occupants, and the general cleanliness of a room. The downward distribution system is the worst offender because it is likely to creat strong drafts near the floor. Velocities in excess of 50 feet a minute over the floor appear to be capable of reinfecting air in this way. This drawback does not apply to upward ventilation systems which discharge the incoming air against the ceiling.

Conclusion. Matters of spacing and ventilation in relation to air-borne infection should be studied more thoroughly. The Army and Navy made a good start in the past war, and their work should be carried out to a conclusion.